BACTERIAL CYTOPLASM AND ORGANELLES

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THE CYTOPLASM

Composition

- **About 80% of the cytoplasm of bacteria is composed of water.**
- **The liquid component of the cytoplasm is called the cytosol.**
- **Within the cytoplasm can be found nucleic acids (DNA and RNA), enzymes and amino acids, carbohydrates, lipids, inorganic ions, and many low molecular weight compounds.**

Functions

- **The cytoplasm is the site of most bacterial metabolism.**
- **Bacterial cytoplasm also contains helical actin-like proteins that along with the cell wall, contribute to cell shape.**

CELL ORGANELLES

The following structures are located within the bacterial cytoplasm:

a) the nucleoid

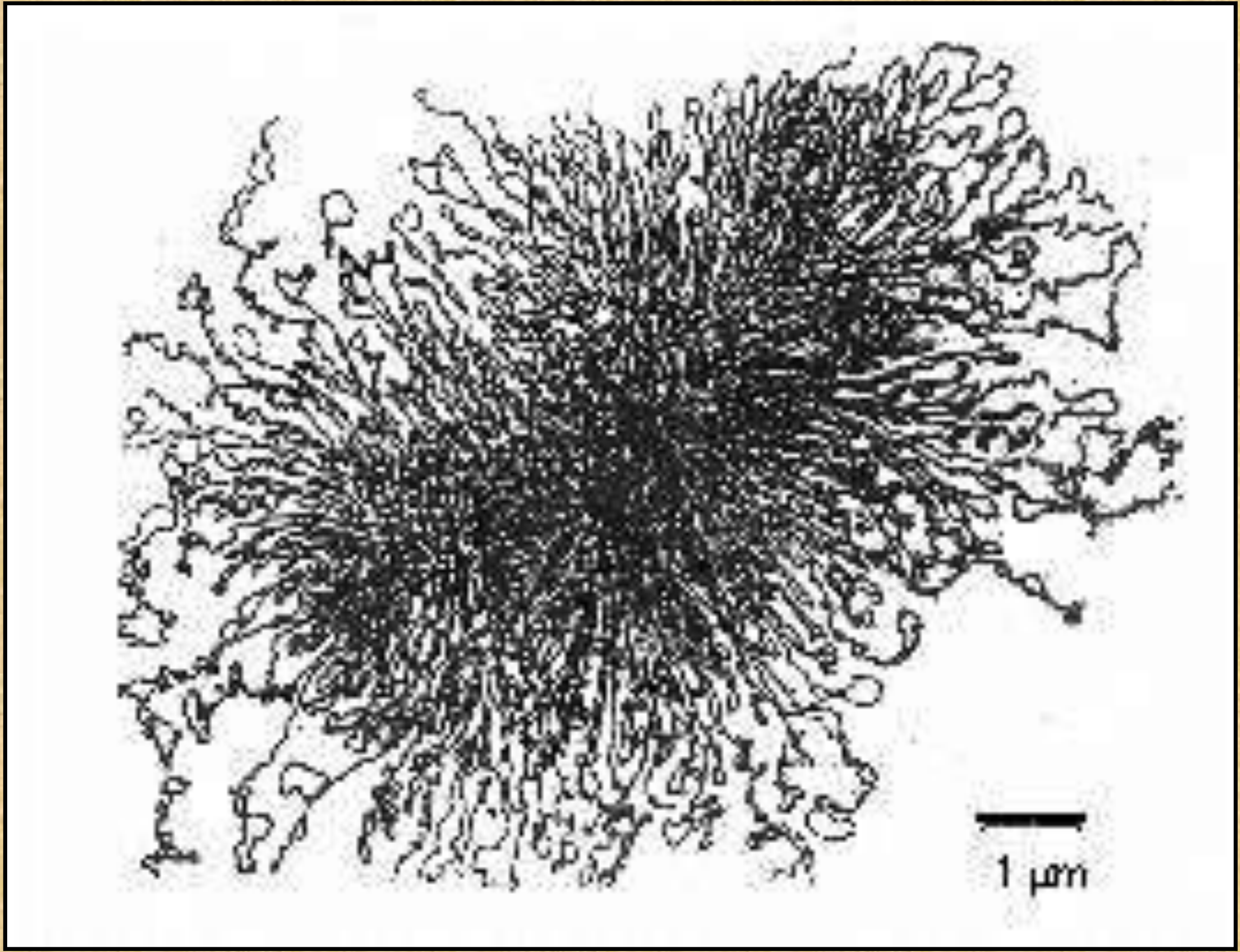
b) plasmids and transposons

c) ribosomes

d) organelles for photosynthesis

e) cytoplasmic inclusion granules

Bacterial Nucleoid



NUCLEOID

- **Bacterial nucleus is referred as nucleoid or chromatin body and it contains chromosome**
- **The bacterial nucleoid has no nuclear membrane or nucleoli; it is diffused in the center of the cytoplasm.**
- **The chromosome of bacteria is a single, long, haploid molecule of double stranded, helical, super coiled DNA .**
- **In most bacteria, the two ends of the double-stranded DNA covalently bond together to form a closed circle.**
- **The chromosome is approximately 1000 µm long and frequently contains as many as 3500 genes.**

Replication of bacterial chromosome

- **The bacterial nucleoid does not divide by mitosis or meiosis**
- **The prokaryotic chromosome replicates in the semi-conservative fashion before distribution to progeny cells.**
- **During DNA replication, each strand of the replicating bacterial DNA attaches to proteins (Fts proteins) at the cell division plane.**
- **As the bacterium grows to full size, the newly replicated chromosomes become separated.**
- **The cytoplasmic membrane coordinates replication and segregation of prokaryotic DNA.**
- **The *Ori C* is located in the cell membrane**

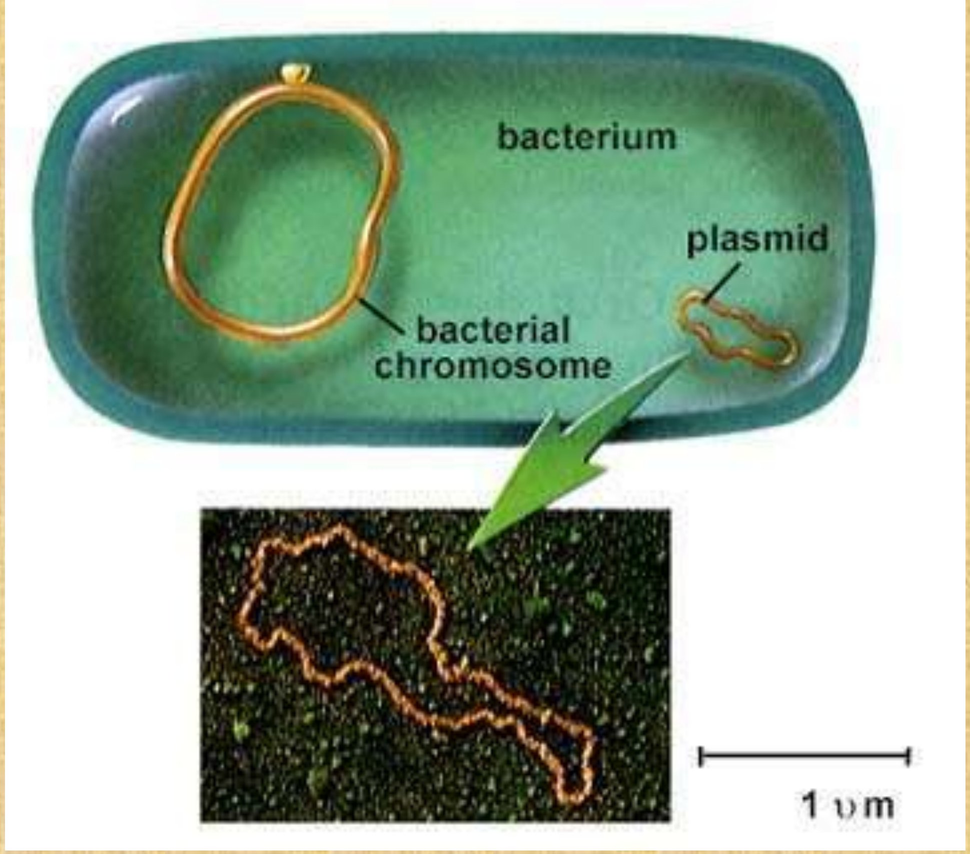
Functions of bacterial nucleoid

Bacterial chromosome is responsible for formation of proteins; transcription and translation are continuous process in bacteria.

Some antibiotics affect bacteria by interefering nucleic acid replication.

- **The fluoroquinolones work by inhibiting enzyme one or more of enzymes 'DNA topoisomearses', e.g. DNA gyrase (DNA gyrase is required for the unwinding, replication, and rewinding of the circular, super coiled bacterial DNA).**
- **Sulphonamides block enzyme required for the synthesis of tetra-hydrofolic acid, a cofactor needed for bacteria to make the nucleotide bases. Without tetra-hydrofolic acid, the bacteria cannot synthesize DNA or RNA.**

PLASMIDS



PLASMIDS

- **Many bacteria often contain small extra chromosomal, covalently closed, circular, double stranded DNA molecules called plasmids.**
- **The plasmids have been described in virtually all known bacteria and even in eukaryotes such as yeasts.**
- **The plasmids are endosymbionts of bacteria, i.e. utilize the replication system of host chromosome for their replication.**
- **Plasmids carry additional genetic information and replicate independently of the chromosome.**
- **Plasmids usually contain between 5 and 100 genes.**
- **Plasmids are not essential for normal bacterial growth and bacteria may lose or gain them without harm.**
- **Plasmids along with nucleoid makes the total bacterial genome.**

Properties of plasmids

Physical properties: circular in shape, consists of one molecule of super coiled DNA, autonomous in existence.

Size: 1 Kb to more than 400 Kb.

Replication: carries genes for autonomous replication.

Curing: can be removed spontaneously or inducibly by curing agents.

Incompatibility: two members of same group cannot co-exist in the same cell.

Transferability : some small plasmids are self-transferable.

Recombination: some plasmids can integrate with the host chromosome (episome).

Relationship with host: not necessary for survival of host cell.

Functions of plasmids

- **Formation of bacteriocins, enzymes, toxins,, such as the tetanus exotoxin and *Escherichia coli* enterotoxin**
- **surface antigens, capsule, pili and other virulence factors**
- **Resistance to heavy metals and antibiotics.**
- **Ability to degrade unusual carbon compounds.**
- **vector for transfer of genetic material from one organism to other.**
- **R-plasmids, found in some gram-negative bacteria, often have genes coding for both production of a conjugation pilus and resistance to antibiotics.**
- **Such plasmids are responsible for transferring antimicrobial resistance to bacteria of same or other species/genus/family by process of conjugation**

TRANSPOSONS

- **transposable or mobile genetic elements**
- **are small pieces of DNA also known as "jumping genes"**
- **may be found in nucleoid (conjugative transposons) or in plasmids and usually have 1 to 12 genes**
- **encode enzymes transpoase that move the transposon from one DNA location to another and integrate there**
- **transpoase catalyzes the cutting and resealing of the DNA during transposition.**
- The **main difference between plasmid and transposon is that plasmid transfer genetic material between genomes whereas transposon transfer genetic material between chromosomes within the same genome.**

- **Integrons** are transposons that can carry multiple gene clusters called gene cassettes that move as a unit from one piece of DNA to another.
- an enzyme called integrase enables these gene cassettes to integrate and accumulate within the integron.
- plasmids can acquire a number of different antibiotic resistance genes by means of integrons.
- In this way, a number of different antibiotic resistance genes can be transferred as a unit from one bacterium to another.

PLASMID VERSUS TRANSPOSON

PLASMID	TRANSPOSON
A plasmid refers to a genetic element that replicates independently of the chromosomes	A transposon refers to a chromosomal segment that can be translocated between chromosomal, plasmid or phage DNA
An extra-chromosomal, self-replicative DNA molecule, naturally occurring in bacteria	A DNA sequence that moves around different positions within a genome
Naturally occur in bacteria and some eukaryotic cells	Occur in bacteria and all eukaryotic cells
F plasmids, resistance plasmids, col plasmids, degradative plasmid, and virulence plasmids are the five classes	Retrotransposons and DNA transposons are the two classes
Self-replicative inside the cell	Not self-replicative DNA segments
Consist of an origin of replication, promoter, antibiotic resistance genes, and multiple cloning sites	Consist of a coding region for transposase, transposable genes, and terminal repeats
Used as vectors to produce recombinant DNA	Used as vectors to insert several bases in insertional mutagenesis
Used to insert new genes into the genome of another organism	Act as mutagens that sometimes cause genetic diseases

LYSOGENS

- **Lysogens are bacteria that have been stably infected with a bacteriophage as a 'prophage‘ (lysogenic cycle)**
- **The bacteriophage DNA is integrated into the genome of the bacterium.**
- **Under special conditions, lysogens can disintegrate to replicate and burst bacterial cell to release new bacteriophage particles.**
- **The gene for diphtheria toxin is carried by a prophage, and only the lysogenic strains of *Corynebacterium diphtheriae* can cause diphtheria.**

RIBOSOMES

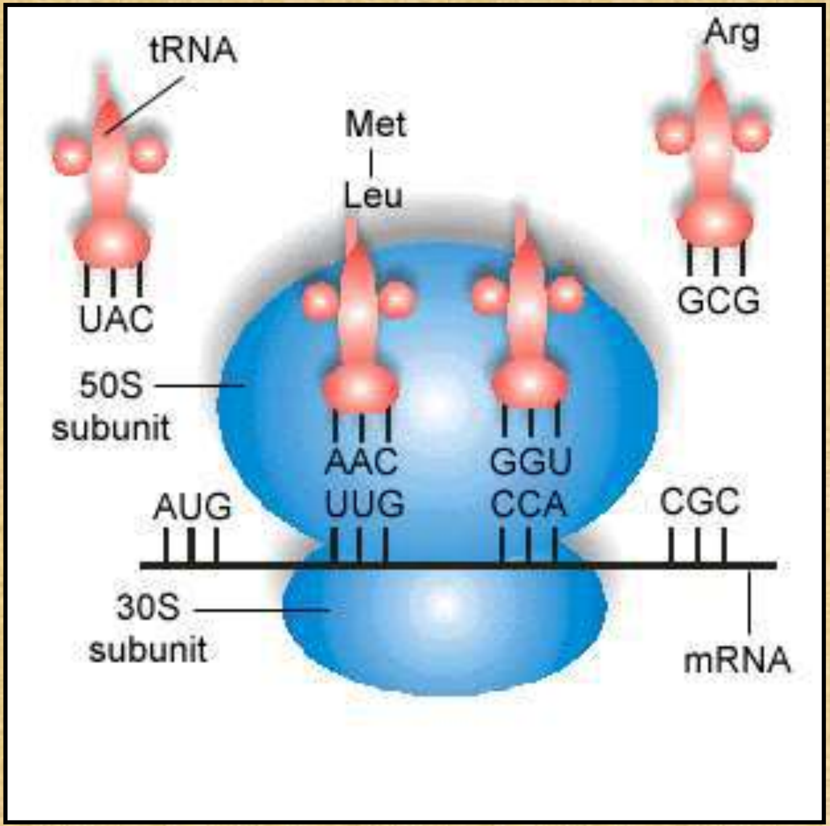
Composition

- **The distinct granular appearance of prokaryotic cytoplasm is due to the presence and distribution of ribosomes.**
- **A typical bacterium may have as many as 15,000 ribosomes.**
- **Chemically, the ribosomes are composed of ribosomal RNA (rRNA) and protein.**
- **The ribosomes of prokaryotes are smaller than of eukaryotes.**
- **Bacterial ribosomes are composed of two subunits with densities of 30S and 50S.**
- **The two subunits combine during protein synthesis to form a complete 70S ribosome about 25nm in diameter.**

Functions of ribosomes

Ribosomes function as a workbench for protein synthesis – translation of mRNA into proteins.

During protein synthesis, mRNA (codon) attach to 30s subunit and tRNAs carrying anti-codon and aminoacid attach to 50s subunit



Action of antibiotics on ribosomes

Many antibiotics alter bacterial ribosomes, interfering with translation and thereby causing *faulty protein synthesis*. The portion of the ribosome to which the antibiotic binds determines how translation is effected.

- **The tetracyclines (tetracycline, doxycycline, minocycline, etc.) bind reversibly to the 30S subunit, distorting it in such a way that the anticodons of charged tRNAs cannot align properly with the codons of the mRNA.**

- **The macrolides (erythromycin, azithromycin, clarithromycin, etc.) bind reversibly to the 50S subunit. They inhibit elongation of the protein by preventing the enzyme peptidyl-transferase from forming peptide bonds between the amino acids. They also prevent the transfer of the peptidyl-tRNA from the A-site to the P-site.**

Common Antibiotics

Antibiotic	Mechanism	Target bacteria
Penicillin	Inhibits cell wall synthesis	Gram Positive
Ampicillin	Inhibits cell wall synthesis	Broad spectrum
Bacitracin	Inhibits cell wall synthesis	Gram Positive – Skin Ointment
Cephalosporin	Inhibits cell wall synthesis	Gram Positive
Tetracycline	Inhibits Protein Synthesis	Broad spectrum
Streptomycin	Inhibits Protein Synthesis	Gram Neg. tuberculosis
Sulfa drug	Inhibits cell metabolism	Bacterial meningitis, UTI
Rifampin	Inhibits RNA synthesis	Gram Pos., some Neg.
Quinolines	Inhibits DNA Synthesis	UTI

INCLUSION GRANULES

- **Inclusions are distinct granules that may be present contained in the cytoplasm of some bacteria as an energy or nutrient reserve.**
- **The number increase under favorable conditions and decrease in adverse conditions.**
- **Examples of the inclusions found in bacteria are metachromatic granules or volutin granules (inorganic phosphate), polysaccharide granules (usually glycogen or starch), lipid inclusions (e.g. PHB granules), sulfur granules, carboxysomes (ribulose 1,5-diphosphate carboxylase), magnetosomes (Fe_3O_4), cyanophycin granules** (nitrogen) **and gas vacuoles.**
- **Some inclusion bodies are actually membranous vesicles into the cytoplasm, which contain photosynthetic pigments or enzymes**.

Cytoplasmic inclusions	Where found	Composition	Function
Glycogen	many bacteria e.g. *E. coli*	Poly glucose	reserve carbon and energy source
Poly beta hydroxy butyric acid (PHB)	many bacteria e.g. *Pseudomonas*	polymerized hydroxyl butyrate	Reserve carbon and energy source
Polyphosphate (volutin granules)	many bacteria e.g. *Corynebacterium*	linear or cyclical polymers of PO4	reserve phosphate; possibly a reserve of high energy phosphate
Sulfur globules	phototrophic purple and green sulfur bacteria and lithotrophic colorless sulfur bacteria	elemental sulfur	reserve of electrons (reducing source) in phototrophs; reserve energy source in lithotrophs

Cytoplasmic inclusions	Where found	Composition	Function
Gas vesicles	aquatic bacteria especially cyanobacteria	protein hulls or shells inflated with gases	buoyancy (floatation) in the vertical water column
Parasporal crystals	endospore-forming bacilli (genus *Bacillus*)	protein	unknown but toxic to certain insects
Magnetosomes	certain aquatic bacteria	magnetite (iron oxide) Fe3O4	orienting and migrating along geo- magnetic field lines
Carboxysomes	many autotrophic bacteria	enzymes for autotrophic CO_2 fixation	site of CO_2 fixation

ORGANELLES USED IN BACTERIAL PHOTOSYNTHESIS

There are three major groups of photosynthetic bacteria - cyanobacteria, purple bacteria, and green bacteria.

- **The cyanobacteria carry out oxygenic photosynthesis, that is, they use water as an electron donor and generate oxygen during photosynthesis. The photosynthetic system is located in an extensive thylakoids membrane system that is lined with particles called phycobilisomes.**
- **The green bacteria carry out anoxygenic photosynthesis. They use reduced molecules such as H_2, H_2S, S, and organic molecules as an electron source and generate NADH and NADPH. The photosynthetic system is located in ellipoidal vesicles called chlorosomes that are independent of the cytoplasmic membrane.**
- **The purple bacteria carry out anoxygenic photosynthesis. They use reduced molecules such as H_2, H_2S, , S, and organic molecules as an electron source and generate NADH and NADPH. The photosynthetic system is located in spherical or lamellar membrane systems that are continuous with the cytoplasmic membrane.**